FLEXIBLE FORWARD CONTRACTS FOR RENEWABLE ENERGY GENERATORS IN DEREGULATED ELECTRICITY MARKETS

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Overview

The amount of wind energy in the United States has increased considerably in the last ten to fifteen years. Wind power from a windfarm can change significantly with rapidly changing wind speeds. Highly volatile nature of wind power presents an obstacle in integrating this zero-cost power source in the day-ahead electricity markets. In this paper, we make use of the increasing amounts of flexible loads in the power system to introduce flexible forward contracts for windfarms. Flexible loads such as electric cars, washing machines, HVAC systems can move their demand between certain hours and only require a certain amount of energy within a relatively flexible time period. The flexibility of these loads can allow windfarms to engage in bilateral forward contracts and enable them to distribute their intermittent energy supply among different time periods depending on the wind conditions. We propose a flexible contract which allows the windfarm to deviate from the committed power amounts in the day-ahead market as long as certain constraints on energy and flexibility are met. One such example would be that the windfarm is allowed to deviate from the committed power amount in the contract as long as it provides some specified amount of total energy at different time intervals.

The flexible load considered in this paper is electric vehicles but our formulations can be extended to other types of flexible loads as well. We consider two types of flexibilities in the load. The first type of flexibility is the total amount of energy required by each car. Second type of flexibility is the flexibility in the starting times at which the load will begin to receive the power from the windfarm. These flexibilities in energy and time allow the windfarm to deviate from the committed amounts in the forward contract, if there is a difference between forecasted and actual wind generation or forecasted and actual real time price. This type of contract would also provide the windfarm with a choice to sell its electricity in the real time market instead of providing the committed amount, in case there is a spike in real time market prices. Since the windfarm gains advantages in terms of the flexibility in the contract and benefits from the real time price spikes, the transaction price of such flexible forward contracts should be set at a level less than the day-ahead market price.

The novel contributions in our work are two folds. First, we propose a new forward contracting mechanism for windfarms in which windfarms are allowed to deviate from their contracted supply amounts in the day-ahead market. We achieve this by having the windfarms make this contract with flexible loads such as electric cars. This allows the windfarms to move the contracted power amounts among different time intervals as long as they meet certain cumulative energy and power requirements at certain time intervals. The flexible contract proposed in this research also does not require any additional changes in the existing deregulated electricity market structure such as addition of penalty functions for supply deficit or reward amounts for oversupply.

Second, we also show the difference in profits of a windfarm if it made a simple forward contract with fixed amounts of supply versus the profits of the windfarm using the proposed flexible forward contract. This additional profit would incentivize both parties in the contract to reduce the contract transaction price below the day-ahead market price. We do this for seven days of a week, using real time price and real time wind generation data, both belonging to the same region of New York state.

The rest of this paper is organized as follows. In first section, we introduce the problem and review the existing literature on the subject. In second section, we propose the flexible contracting mechanism and provide the equations describing the contraints on flexibility. We describe the simulation setup in the third section. In fourth section, we show and explain the results of simulating the flexible contract for windfarms for seven days of a week. We conclude and summarizes the paper in section five.

Methods

We use stochastic optimization to maximize the payoff for the windfarm in the flexible forward contract. A stochastic linear program is used to optimize the operation of windfarm to supply the flexible load while satisfying the constraints on the flexibility in load.

Results

We consider a 5 MW windfarm which enters into different types of forward contracts to supply power for 24 hours starting at 17:00 Hrs. We repeat this process for seven days of a week. The first set of results show the revenues of windfarm when it enters into a fixed forward contract with a load comprising of electric cars. We vary the number of electric cars from 400 to 600 in increments of 50 and observe the revenues of windfarm in $/MW of windfarm capacity when the load does not offer any flexibility in duration or amount of load.

Second, we try different levels of flexibility in the duration of load, ranging from 0 hour to 9 hours of flexibility in charging of the flexible load (electric cars). We again try different number of cars varying from 400 to 600 in incerements of 50. We show the revenues of windfarm for these different levels of flexibility using a forecast of real time electricity price and then we calculate those revenues when the actual value of real time electricity price is known in advance.

In both cases, we provide the revenues of windfarm in $/MW of windfarm capacity. The revenues of windfarm for the load of 500 cars for the two different contract types are shown in Table 1. Our results show that the windfarm revenues increase as the flexibility in duration and quantity of flexible load is increased and the proposed flexible forward contract increases the payoff for renewable generators.

Table 1: Revenues of windfarm in $/MW of capacity for the two different types of forward contracts with a load of 500 cars, when actual value of real time price is used in the forward contract optimization.

Flexibility in duration	Fixed contract	Flexible forward contract
0	1,241	1,362
1	N/A	1,381
2	N/A	1,392
3	N/A	1,400
4	N/A	1,405
5	N/A	1,411
6	N/A	1,417
7	N/A	1,423
8	N/A	1,431
9	N/A	1,441

Lastly, we also show an example of a transaction price for the flexible contract which is less than the day-ahead market price and results in lowering the electricity cost for the flexible loads, while increasing the revenues for the windfarm as compared to a fixed forward contract. This shows that the proposed contract is beneficial for both flexible load and the renewable generator.

Conclusions

Our proposed contracting mechanism allows a renewable power supplier to enter into a contract with flexible loads and take advantage of this flexibility by changing its power dispatch from the committed amounts. If the generation is less than the committed amount in the contract, the supplier can change the power dispatch as long as it satisfies the conditions on cumulative energy up to different time intervals and remains within the limits of flexibility. Such a contract also allows the renewable energy supplier to sell its power in real time market when real time prices are high. This type of scheme provides additional benefits to the power supplier. As a result, the transaction price of such a contract could be set less than the day-ahead market price and this would benefit the electricity consumer as well because they would be paying less than the day-ahead market price in this situation.

We observed the results of a completely fixed forward contract and the proposed contract with completely flexible load. The results show that a greater degree of flexibility in the load leads to larger benefits for the renewable generators while reducing the costs for the load entities.